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Research Article

BIODEGRADABLE PEA-PEEL FILM REINFORCED WITH CELLULOSE NANOFIBERS ISOLATED FROM BANANA PEEL

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A B S T R A C T

With the rising era of agro-based industry in India, waste associated with these industries also increasing rapidly. The supply chain including production, preparation, processing, distribution, and consumption drastically produces a large volume of waste, so further utilization of this waste is a necessity. In addition to this, the graph of plastic packaging usage is already a headline in India. Even after the restriction, petroleum-based plastic packaging is still a member of every Indian house and used by almost every shopkeeper, because plastic has good mechanical strength and barrier properties along with this the cost is quite low. However, underestimating the problems associated with plastic packaging like soil pollution, air pollution due to burning, water pollution, which affects marine life, etc., would cause a serious threat to the environment hence; alternatives for plastic packaging should be made to save our environment. By utilizing the waste material for making a biodegradable packaging film can consider as a good option as it might be cost-effective and low graded shopkeepers can also afford it, but to make it more successful, its mechanical strength needs to be good. Cellulose nanofibers (CNF) based sources have proved in researches that it can increase the mechanical properties of any biofilm. Research article based on nanocomposites made of banana starch incorporating banana peel CNF results in a good tensile strength (11.1MPa) compared with other bio-based films such as mango peel film (2.85MPa), banana peel with 4% corn starch film (3.47 MPa), corn starch film (3.59MPa), potato starch film (4.87MPa), pea peel film (5.96MPa). The waste associated with pea peel and the banana peel is very high and can be found at zero cost. The review paper aims to study packaging materials, nutritional properties of banana peel, pea peel and to this, preparation of biodegradable packaging film which could reduce the problems of plastic.

INTRODUCTION

Packaging is a word used for any product that is used to hold, protect, handle, distribute, and for the presentation of goods, from raw materials to finished products, from producers to consumers. The packaging is usually divided according to the basic raw material like metal, glass, polymer, paper cardboard, and other types but since the most commonly used material is ‘plastics’. [1]. Plastics are usually found in a wide range of synthetic or semi-synthetic materials, typically uses polymer as their main ingredient. Most of the plastics derived from fossil fuel-based petrochemicals like natural gas or petroleum [2]. Properties of food products are only maintained when proper packaging material and processing are used. [3]. But, concerning environmental consequences, many recent industries use variants made from renewable materials such as derivatives of corn or cotton.[1]

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In the packaging industry, food packaging accounts for 50% of the plastics derived from fossil fuels and can be classified as thermoplastic and thermosets. [4]. Thermoplastics can be processed and reprocessed using heat with the ability to reprocess and makes them recyclable, along with the molding property i.e. shaping & sizing ability, for eg-low-density polyethylene (LDPE), polypropylene (PP), polyvinyl chloride (PVC), polyethylene terephthalate (PET), high-density polyethylene (HDPE), polystyrene (PS), and expanded polystyrene. [5, 6] On the other hand, thermosets cannot be reprocessed by heat once they are formed, they can’t be recycled again and thus, not much suitable in packaging. [7, 8]. Besides this, plastic has many benefits too like lightweight, strong, visually aesthetic, flexible size, shape, and cheaper price also have desirable properties like a good barrier towards O2, aroma compounds, tensile strength, and tear strength. Because of these benefits, there is high usage of plastics even it has been banned, because it comes with a slew of environmental consequences, like long decomposition rates and damage to natural ecosystems. [9]. When food is thrown away, it's done along with the packaging material where it was contained, which directly causes effects in the eco-system such as it causes soil pollution, water pollution, toxicity to the animal stomach, threat to aquatic and marine life, and many more uncountable damages. These fossil fuel plastics are persistent in the environment and take many years to degrade. [10]. As they do, they break into microplastics, which can easily enter the food chain when consumed by, for example, fish, leading to bioaccumulation. Growing environmental concerns have placed packaging into a more serious discussion as it is a common as well as a constant source of high amounts of plastic waste and this has brought about the need to do extensive and economic research into renewable alternatives. [11]. Synthetic polymers such as plastic bags, foamed plastic cups, plastic beveragebottles, etc have long been the foundation of plastic packaging materials, but, because these polymers are non-biodegradable utilization of this in packaging material led to a serious ecological problem. [11,12].

Fig 1

Figure 1, 'The lifecycle of plastics' [13] depicts the approximate degradation time of the plastic comprising products which generally uses on daily basis. It justifies the fact that plastic-based waste products take a very long time to degrade than any other wastes and hence, cause very serious damage to the environment. This tells one of the reasons that why plastic usage should ban or reduce.

Fig 2

Figure 2, As per the report article published by "THE ECONOMIC TIMES"[14], figure, says about the waste side story that India generates 25,940 tonnes of plastic waste every day which is almost close to the weight of 9,000 Asian elephants and 86 Boeing 747 jets. 10,376tonnes a day plastic waste is uncollected and 1/6th of plastic waste generated by 60 cities out of this half of the waste comes from main cities Delhi, Mumbai, Bengaluru, Chennai, and Kolkata.

Having concerns about plastic related issues, Biodegradable non-plastic packaging and films due to their eco-friendly properties have begun to immerge as an alternative to standard plastic packaging.

Biodegradable Packaging

Biodegradable usually means capable of being broken down (decomposed) by the action of micro-organisms, and when a packaging material comprises this property is said to be biodegradable packaging. [15].

Biodegradable packaging is usually made from eco-friendly materials, easy to recycle, and with the requirement of less energy, they are non-toxic materials. Biodegradable packaging has many advantages over plastic packaging but they have its limitations too such as long-term usage of biodegradable packaging from plant sources may lead to more requirement of plant matter, they too require a special facility for composting and landfilling is another issue emerging due to biodegradation. [16].

Many retailers and manufacturers are looking for sustainable packaging solutions, and terms such as 'recyclable', 'compostable', and 'biodegradable', 'bioplastics' are commonly used about "green" packaging. [17]. But, although these three words are frequently used together, often interchangeably, they refer to different processes, describing further-

'Recycling' is the procedure of renovating used materials, keeping products away from a landfill. There are certain limits to how many times a material can be recycled for example standard plastics and paper, can be recycled few times before they become unworkable, whereas some other plastic materials, like plastic glasses, can be recycled an infinite number of times. There are varieties of plastic packaging which came into existence, some are commonly recycled, others nearly never recyclable. A study was done by eco-cleaning products brand E-cover, has found that two-thirds of British customers recycle frequently, however, as many as 37% admit they don't always aware of a product's packaging can be recycled or not. [18].

'Compostable' procedure involves taking compost system in bio- decomposition and breaks them down into carbon dioxide, water, biomass, inorganic compounds, so became indistinguishable. For example-containers, coffee pods, food packaging compostable materials, cups, plates, etc. All compostable products must be certified as compatible with ASTM or other international standards to ensure that the finished products will not environmental problems. [19].

'Bio-plastics' are made from marine or plant-based materials (such as corn and sugarcane) instead of petroleum and, therefore, are considered more environmentally-friendly, because their production requires less usage of fossil fuels and generates the rarer amount of greenhouse gases as compared with petroleum-based plastics. Some bio-plastics are also made from waste agriculture byproducts, such as potato peelings, which endorse "recycling". However, despite what their name suggests, not all bioplastics are biodegradable. [18]. For example, poly-lactic acid (PLA) bioplastic is biodegradable, while a poly-ethene terephthalate (PET) bio-plastic is not. Predictably, this confuses that many bio-plastics are not disposed of appropriately. Still, the bioplastic industry perceives an inspiring growth rate around the world, which can be considered as an opportunity for the biodegradable film market. [17,18].

Biodegradation is a term used for any packaging is a process of defragmentation, initiated by heat, moisture, and/or microbial enzymes, which transforms longer molecular substances into smaller compounds. [20]. It can also be simply defined as a process by which substances are broken down by living microorganisms such as bacteria, fungi under certain conditions (temperature, humidity, etc.). The term itself is quite vague though, as it does not define the length of time needed for products to decompose. [15, 21].

Generally, Bio-based materials can be obtained from two sources-

1. The direct production of bio-based polymers through microorganisms, algae, or plants. Examples of such polymers are oligosaccharides (starch, inulin, pectin, chitin, cellulose, hemicellulose, and chitosan), polyhydroxyalkanoates (PHA), polysaccharides, some more example proteins, poly(amino acid)s, or lignin can be found.[22,12]
2. The production of bio-based monomers and their advanced polymerization. For example, the most extensively known lactic acid (and the respective polymer, PLA). [22, 23, 12].

The biodegradable polymers that have found solicitation in packaging are starch, cellulose, chitosan, poly(lactic acid) (PLA), polycaprolactone (PCL), and polyhydroxy butyrate (PHB), etc. Many materials can be mixes or blends containing synthetic components, like polymers and additives to improve the functional properties of the finished product thereafter, expand the range of application. However, if additives and pigments are also based on renewable resources, one can obtain a polymer with approximately 100% weight of biodegradation compounds. [24, 12, 22].

Packaging forecasting done by Packaging Europe in December 2019, analyzed that the global bioplastic production can increase to approximately 2.4 million tons by 2024 which presently was 2.1 million tons in 2019. The worldwide biodegradable film market probable to be USD 1.1 billion in 2020 and likely to reach USD 1.5 billion by 2025. [25]. Due to COVID-19, an eruption on demand for biodegradable films in the agricultural industry is considered to be slightly affected at the global level, due to disruption in the supply chain. However, the impact will not be very huge, as the industry and the crop production have not been suspended. [24].

The debate about which packaging (recyclable, biodegradable, or compostable) is best for the environment is ongoing and there's still no particular answer to this question. All of these solutions come with their advantages and limitations but a small step forward towards more sustainable alternatives to standard packaging can achieve a better land for all. Out of all this, cellulose has been proven as an effective material to be used in biofilms and cellulose nanofibres have a given lot of proofs and results which shows that it can improve the lacking mechanical property of any biodegradable films.

Biodegradable packaging can be the best alternative to plastics; they offer the best packaging solutions for perishables against microbes and contribute to a healthy environment. Even if biodegradable packaging has not reached its full bloom yet to save our eco-system, the judicial use of this alternative packaging is worthwhile. [16].

Cellulose Nanofibers (CNF)

Cellulose is the most abundant natural biopolymer and is a linear homo-polysaccharide composed of β-D-glucopyranose units connected by β-1–4-linkages with a repeating unit of cellobiose, and it is considered an alternative for petroleum-based materials for packaging. [26]. commonly, cellulose consists of both crystalline and amorphous domains. There are three hydroxyl groups in a monomer of the cellulose structure that form hydrogen bonds, which play a vital role in the physical properties and crystalline packing of cellulose. [27].

CNF primarily consists of cellulose fibrils surrounded in a learning matrix, thus, these nanofibres may provide superior rigidity, tensile and flexural properties. CNF packaging determines strength and stiffness close to that of polyolefines and can be seen as a low cost "green" substitute for application in food packaging and conservation**.** [28, 27]. Therefore, cellulose nanofibres (CNF), are specifically targeted by most producers.

The biodegradable-based packaging market is increasing due to the necessity for:

- Environmentally friendly products
- Improving food quality and safety during transportation.
- Replacing petroleum-based, glass, metal, wax/plastic-coated products.

Nanocellulosecan be defined as a long, flexible, and entangled network of microfibril. Strands of spaghetti or strands of hair are two worthy examples for envisaging the structure of CNF. CNF includes both amorphous and crystalline regions and holds a high aspect ratio. CNF can be isolated from cellulosic fibers using various mechanical or chemo-mechanical processes, including high-pressure homogenization, micro fluidization, micro grinding, high-intensity ultra-sonication, electrospinning, and steam explosion, but each technology has its advantages and disadvantages**.** [27].

Because of their promising characteristics, Nano fibrillated cellulosic fibers have been extensively utilized in a variety of applications in several fields, including medical, packaging, paper and coating, electronics, and membranes [29]. The past era has witnessed weighty progressions in the enlargement of biodegradable plastic packaging, predominantly from renewable cellulose-based biomaterials. These advancements are focused on obtaining upgraded food quality and safety through packaging with the move towards globalization. Researchers have sought several alternatives to minimize the environmental impact of conventional polymers, including starch as it is plentiful, inexpensive, and degradable, so can be employed to produce biodegradable films. [30]. However, if scientifically approaches starch for film making, it is necessary to improve its mechanical and barrier properties, because starch films are water-soluble, brittle, and challenging to process. Using nanotechnology to develop films based on polymer nanocomposites containing nanometric fillers might be a new approach to improve the mechanical and barrier properties of a given polymer. [29,27].

By considering all the above information's, a biodegradable packaging film made of waste materials will surely contribute to a healthy environment as plant-based cellulose nanofibres have generated great interest because they exhibit a large surface to volume ratio, better tensile strength, stiffness, and flexibility, and good dynamic mechanical, electrical, and thermal properties as compared with other commercial fibers

LITERATURE STUDY

After knowing all the information related to the problems related to plastic usage along with properties associated with biodegradable packaging and cellulose fibers one can agree with the fact that using biodegradable packaging can surely overcome the environmental issues that we are facing today. It is believed that biodegradable polymers will replace synthetic polymers at a minimum cost, thereby producing an optimistic effect both environmentally and economically [31]. Many kinds of research been done and are still going on, making of biodegradable films which are environment friendly is a highly concerning topic nowadays and with this different kind of biodegradable films has also been made till now like- corn and potato starch-based films, potato starch-based film, banana starch, purple yam starch incorporated with chitosan, and much other starch-based films from byproducts of fruits and vegetables, pectin based films, biocomposites, etc. has already come into headings. All kinds of films have advantages but limitations too concerning mechanical properties. So thus, there is a requirement to overcome these limitations and make an improved film.

By considering all the facts related to the use of cellulosic nanofibres (CNF) it can be concluded that if used in packaging, will somewhere minimize the costs of packed products due to their wide availability and low cost. It will also preserve the environment due to its recyclability and reusability. An innovative approach with utilizing CNF or by incorporating them in the biodegradable film can be a beneficial tool for the development of sustainable packaging with improved characteristics and qualitative environmental management of packaging materials.

An effective design of CNF based packaging may show qualitative and quantitative functioning of the product throughout its entire life cycle. Nowadays, consumer demand for more environmentally friendly products has led to the development of packaging materials derived from renewable sources with prompted biodegradability, but with the same mechanical properties as commonly used materials. The global plastics sector currently produces roughly 250 million tons annually [32]. Over 99% derived from fossil fuels, and most of it are not biodegradable. Giving the priority to this problem, In recent years, nano cellulosic materials have attracted the interest of scientists for maximizing the mechanical and barrier properties of packaging materials.

Bio-based material with CNF is 100% fully biodegradable and is a prime candidate to replace petroleum-based packaging [33]. Inadequacies of bio-based polymers are weak mechanical and barrier properties can be significantly heightened by the use of nanocellulose-based materials. The use of CNFs can extend the shelf life of food and has ability to improve the food quality as they can serve as carriers for a variety of active substances, such as anti-oxidant and anti-microbial [28].

Cellulose nanofibrescan be extracted from cotton, banana, oil palm, bamboo, wheat, rice, etc., as these are readily the source's of cellulose. The selection of sources is dependent on the local availability of the fiber, chemical components for usage, and economic feasibility [27]. the use of renewable material will contribute to environmental sustainability by reducing greenhouse gases. Numerous research and progress activities have been performed by researchers to encourage the use of biodegradable and eco-friendly packaging materials to replace existing conventional packaging materials available in the market, such as conventional plastic or glass packages [34].

Tensile Strength- From the experiment, a tensile strength of biofilm was observed to be 5.96 MPa. This was observed higher than the tensile strength (2.85 MPa) of bio-film developed from mango puree [35, 41]. Banana peel with 0% starch gives tensile strength of 1.33MPa whereas with 4% corn starch gives 3.47MPa, the tensile strength of the films is far smaller compared to previous studies on starch-based films.

Table 1

Reference No.	Tensile Strength	Water Absorption Test	Thickness, Density, Moisture Content.	Solubility In Water	Sem
[35]	5.96MPa	-	Thickness 70 microns.	2.46% Whereas from soy protein- 7.37%	It was slightly porous, smooth and exhibited no breakage at the surface and specifically the film appearance was transparent.
[37]	11.1MPa	30%	Thickness 86 microns, density 1.17g/cm^2 , M.C. 14.5%	29.0%	Nanocomposites presented non-homogenous structures; i.e., irregular surfaces with imperfections.
[38]	B.P. film with 0% starch-1.33 MPa, with 4%C.S.-3.47 MPa..	With 3% starch- 60.65%	-	-	-
[39]	Rice starch & corn starch 7 & 3 gm resp.-12.5MPa	-	Thickness- 250 microns(0.25mm) M.C.-11.7%	11.5%	Biodegradability of 48.73% was achieved in 15 days for the sample placed in the soil at a depth of 3 cm.
[40]	Corn starch- 3.59MPa Potato starch- 4.87MPa, Potato peel starch-1.3MPa, Mango peel- 2.85MPa	Banana peel- 63.95%, corn starch-22.69%, potato starch-32.35%	Thickness of several starch films made up of potato, rice, wheat, gelatin, and sorghum and found 53 to 63 microns.	-	-

Studies stated that potato-based bioplastics have a strength of 4870 kN/m2, cassava with 4500 kN/m2, and corn-based bioplastics with 3590 kN/m2 compared to this banana peel film delivers a lesser value of strength compared to other starch-based sources[38]. With a strength of 12.5 MPa, the starch crosslinking of ether or ester linkages amongst hydroxyl (-OH) clusters in starch molecules improved mechanical properties, due to the density increased by crosslinking [39, 40].With 11.1 MPa, Compared with the control film, the tensile strength and Young's modulus of the nanocomposites increased upon the addition of cellulose nanofibers, whereas the elongation at break decreased. This means that incorporating cellulose crystallites into the starch matrix results in strong interactions between cellulose crystallites and the starch matrix, which restrict the chain motion of the starch matrix. It shows higher tensile strength as compared with non-cellulose containing biofilm.[37]

Thickness- Thickness of the developed biofilm was found to be 70 µm, whereas, for the cornstarch-based film [42] results from thickness ranging from 30µm to 100µm.The average thickness of the bioplastics is found to be 0.25 mm (250 microns). Agreeing to protocols of the Government of India, the thickness of plastic bags must not be a lesser amount than 50 microns, and the result for prepared bioplastics having a thickness of 250 microns which concluded that it can be used for preparing carry bags. The thickness of numerous starch holding films prepared by potato, rice, wheat, gelatin, and sorghum are found to have 53 to 63 microns. In this result, the thickness is higher, which may be due to the presence of corn starch. And that for moisture content is 11.7%, the solubility of all the starch films followed the same tendency as per the expectation, while the hydrophilicity of the film falls with the addition of rice starch. Thickness, Density, And Moisture Content- With the results shown in the table it can be concluded that the incorporation of cellulose nanofibers elicited a statistically significant the difference in the density values obtained for the films, with the control film presenting higher density than the nanocomposites the structure of the nanocomposites is more open, more porous, and less dense than the structure of the control film. The incorporation of cellulose nanofibers also reduced the moisture content in the nanocomposites, because the cellulose nanofibers have a lower affinity for water as compared with starch. [44].Thickness of several starch-based films has taken showing good thickness property.

Water Solubility- Water solubility may be described as a maximum possible concentration of a material dissolved in water. Bio-films prepared from pea peel seemed to be easily dissolved in water and solubility was 2.46 percent and soy protein-based biofilm [43] observed 7.37 percent water solubility which was slightly higher than the recorded value in the study. With 29.0% water solubility, the incorporation of nanofibers into the starch matrix did not diminish the solubility in water. The defects in nanofibers are caused by mechanical treatment, which would act as crack initiators, probably declining the nanofibers network inside the material. Water solubility was the main property able to distinguish the starch type through the film formation methods, based on starch being related to the amylose content in the grains, found in the experiment was 11.5%.

SEM- (Scanning Electron Microscopy Analysis) SEM picture evaluated the surface morphology of developed bio-film at 50 µm and it was observed from the image that to some extent, the film was porous, smooth, and displayed no breakage at the surface and precisely the film appearance was transparent. Incorporation of cellulose nanofibers significantly changed the microstructure of the nanocomposites as compared with the control film (FC). Nanocomposites offered non-homogenous structures; i.e., irregular surfaces with limitations, while the normal film displayed a more uniform and smooth surface. Regarding the cross-section of a biofilm, the nanocomposites demonstrated less dense and less homogeneous polymeric structures with small cracks, as compared with the control film [59].The surface structure of the material had lost its uniformity, and flaws were evident, the sample displayed a significant variation in the structure. The SEM images evidenced the biodegradation evolution that arises over the bioplastic film, with the presence of faults and loss of filmy nature.

Water Absorption Test- 30% water absorption capacity shows that the water uptake for the control film and nanocomposites reinforced with cellulose nanofibers as a function of time.The water absorption of the plasticized starch BP film was carried out at room temperature for 24 hours for maximum possible results. BP film with 3% corn starch concentration showed water uptake of 60.65% and with 4% uptake of 63.87%. Probably films have a water uptake percentage of more than 50% because biopolymers are hydrophilic[38]. Starch comprising films absorbs more water which ultimately reduces the mechanical strength of the film.

So, out of various peels and starch-based films, pea peel waste might be an option to utilize them for making a biodegradable film as the pea processing industry involves preserving green peas by freezing and marketing them for seasonal limitation and producing a very high amount of waste as a by-product and inappropriate disposal of this waste not only results in environmental degradation and pollution, but also loss of valuable biomass resources, and along with this the results of a pea peel based film showing better results but more value addition can be done in the film to make a good property biofilm so for this cellulose fibers can be incorporated from banana peel waste as good amount of cellulose content is present in banana peel and also with this the result based on cellulose on banana peel starch shows improved properties. More detailing about pea peel as well banana peel is discussed further.

Pea Production and Pea Peel Properties-

Green Peas, also commonly known as garden peas is one of the vegetable crops in India and fundamentally this crop is cultivated for its green pods. Pea (Pisumsativum) is a cool-season crop and one of the most important legumes, grows either alone or in combination with small grains, in the temperate climatic regions and is widely consumed as a legume or vegetable throughout the world for satisfying the purpose of human feeding as well as animal feeding. Green Peas are uses in vegetable cooking, in soups & cold preserved food as well. Green Pea straw is a nutritious fodder and is used for any animal (livestock) feed. [35].

Major Green Peas Creating States in India:- Uttar Pradesh, Himachal Pradesh, Orissa, West Bengal, Punjab, Karnataka, etc.[45].

The pea is believed to be one of the chief vegetables to be farmed, probably at first in India. Uttar Pradesh is the major ground pea growing state. Post-harvest losses of peas can vary extensively from system to system and maybe somewhere between 2 -50 percent. To avoid the post-harvest losses observes of peas comprise grading, blanching, freezing, dehydration, etc. Frozen pea processing endures rising as demand for peas of this form increases. With pea harvest and transportation speed, increasing there is a growing need for improved storage. [46].

Table 2 Proximate composition values of pea peel [35]

S. No.	Parameters	Variables
		Mean± S.D
1.	Crude Protein (%)	19.80±1.65
2.	Ether Extract (%)	2.27±0.61
3.	Total Ash (%)	5.65±0.33
4.	Crude Fibre (%)	1.84±0.011
5.	Acid Detergent Fiber (%)	54±1.00
6.	Lignin (%)	25±1.41
7.	Cellulose (%)	30±1.58

Table 2, revealed that the experiment that the value of acid detergent fiber obtained in pea peels was 54 percent, whereas, contents of lignin and cellulose in pea peel were calculated as 25 % and 30 % respectively. The percentage of cellulose and lignin was high which justifies that the pea peel waste is lignocellulosic and hence might show the property to give a biodegradable film with good strength.

Pea peel waste is one of the undervalued and unused sources of energy that has the potential to be used in some way.

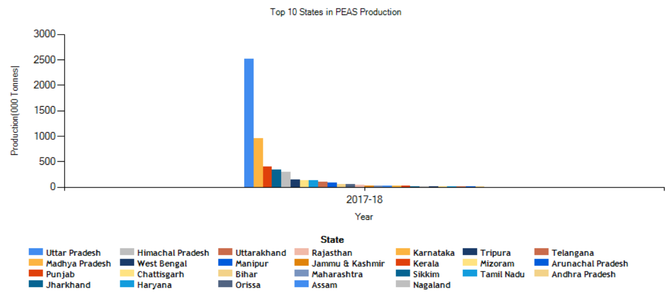

Figure 3 According to the APEDA AgriXchange report (2017-18) [47] showing Indian production data of green peas across all the states with a total production of 5,103.31(000tonnes).

Based on India's annual production of a pea, more than 1 million tons of pea peel waste is caused alone in India, out of which a large amount is discarded as waste. With the progress of the agro-based industry in India, the manufacturing of wastes from these industries increased speedily by quantity as well as by variability. These industries produce a bulk amount of waste, ensuing from the research, production, preparation, and intake of food. One report reading was aimed to asset the nutritional value of waste pea peels and to apply them for developing the bio-degradable product through value addition in an efficient way. On an accumulation, the left-over pea peels have a high nutritious value of rough protein (19.79%), and a good quantity of ash (7.87%), fat (2.27%), and fiber (1.84%). [35].

Pea peel wastes are obtainable in bulk at zero cost, can be cast-off without much quality degradation, and transformed into useful products of higher value as compared to conventional green fodder, after biological treatment. Therefore, in this review paper, the recycling and utilization of pea peel waste were considered as an important step in environmental protection, energy availability, and economic development through converting pea peel waste produced by the pea processing industry into a biodegradable product or bio-film.

The biodegradable film developed on research [48] has concluded that pea peel film has a good tensile strength (5.96 MPa), thickness (70 µm), and water solubility (2.46%). Therefore, bio-film can be a substitute for synthetic plastic with the improvement of employment generation, energy repossession, and livelihood security, which would ultimately lead to bearable development [35]. However, to increase its mechanical strength and barrier properties incorporation of cellulose fibers can be a good option to improve the characteristics of this biodegradable packaging material. More advantages related to this cellulose fiber were already discussed above. After this have a look at banana peel and its respective properties below.

Banana Production and Peel Properties

The second most essential fruit crop, Banana (*Musa* sp.), in India following mango is a fruit having accessibility, affordability, varietal range, taste, nourishing and medicinal value creates it the beloved fruit among all classes of people. [49]

Banana is a very widespread fruit due to its little price and wholesome value. It is consumed fresh or cooked form individually as ripe and raw fruit. Banana is a good source of carbohydrate, vitamins principally vitamin B. It is also a worthy source of potassium, phosphorus, calcium, and magnesium. Plantains or cooking bananas are rich in starch and have a chemical composition similar to that of potato. [50]. Ripening of fruits involves, growth in soluble sugar, reduction in starch and hemicellulose, and a slight increase in protein and lipid content.

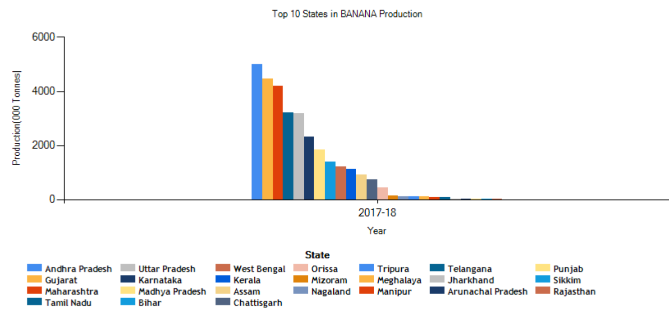

Figure 4 reveals about the banana production across Indian states including highest peak in Andhra Pradesh with 5003.07 (000tonnes) with a total production of 27,940.51(000tonnes) (2017-18) **[51]**

Most of the palatable bananas are cultured mainly for their fruits; hence banana farms could generate numerous tons of underused by-products and wastes. Lacking proper agricultural waste management practice creates a huge amount of appreciated unexploited commodity that will ultimately be affecting the eco-system. Although banana by-products have been used for wrappings foods, clothes and used in various ceremonial occasions and the usage expands through cultural diversification. [52,29].

The post-harvest losses of banana have been predictable in the range of 4-4.7 quintal on or after harvesting, 3.16 quintal in diseased fruits, 2.08 quintal while storage, transportation 2.5 quintals, and rest at the consumption stage. It was experiential that the involvement of mechanical damage to banana loss might be credited to the inefficient handling during harvesting and transport of bananas. The novelty in managing a huge amount of agricultural waste or biomass is an endless challenge and recent leanings favor the utilization of this biomass for value-added purposes to accomplish the need in the areas such as renewable energy, fiber composites and textiles, food alternatives, and livestock feed. [53].

Readings on the cellulosic fibers from farming wastes like-from oil palm industries designated the great potential of by-products to convert the commercial raw material such as paper and fiber composites. [29]. Many types of research surfaced new and alternative ways of crafting novel products and their applications with the value-added approach at the cost of recycling banana agricultural wastes. There is a constant need to create and discover new products with value-added bio-resources as means to develop a sustainable evolution. Due to the high demand for foodstuffs, energy, and other essential needs, gradual improvement in the current technological development towards utilizing alternative resources in many industries is necessary to cater to the desires of the ever-increasing world inhabitants. [52]. The edible part of the fruit constitutes only 12 wt% of the plant; the remaining parts become agricultural waste and cause environmental problems. [37].

Banana peel (BP) covers about 30–40% of fresh banana. The configuration of ripe BP includes crude protein (8%), ether extract (6.2%), soluble sugars (13.8%), and total phenolic compounds (4.8%). The main components of BP are cellulose, hemicellulose, chlorophyll, pectin, and other low-molecular-weight compounds [54]. Banana is the second-largest shaped fruit, accounting for 16% of total fruit production globally. It is one of the useful commodities that lives in a short time, is easy to be cultivated, and can be harvested throughout the year. The outer skin of the banana is only used for animal feed and organic fertilizer. It indicates that the banana peel waste has not been optimized yet.[36]. Banana yields a huge amount of cellulosic waste which is disposed of in landfills. As the peels rot, they produce methane gas which accounts for 20% of methane emissions, thus forming a major contributor to global warming. Henceforth, redirecting these solid wastes of banana peels into something useful and beneficial is essential. [52].

Cellulose is an abundant polymer in nature, environmentally-friendly, cheap, and biodegradable. The use of cellulose nanofibers as reinforcing elements in matrices improves thermomechanical properties, decreases the sensitivity of polymers to water, and preserves biodegradability. Indeed, mixing cellulose nanofibers with polysaccharides (such as starch) improves mechanical properties. [55].

Researchers have quarantined nanostructures from various agricultural remainders example soy hulls, corn husk, coconut husk, and sugarcane bagasse, pineapple leaf. [37]. since the banana peel is rich in cellulose, this material is possibly applicable as a highlighting component in high-performance composites, increasing its commercial value and providing a purpose for this byproduct.

Preparation and qualitative analysis
Biodegradable film

1. Pea peels are together collected of the well-known amount and transformed into small pieces, cast-off as an antioxidant and preservative source. After this, peels are dipped in sodium metabisulphite (0.2 M) solution for around 45 minutes.
2. Pea peels are boiled in refined water for about 30 minutes.
3. Water is transferred from the beaker and peels are now left to dry on filter paper for around 30 minutes.
4. Next the peels will dry out, they are sited in a beaker, and using a hand blender, the peels were pureed till a uniform paste is formed.
5. Known amount of pea peel paste (approx. 25gm) is placed in a beaker. About 3 ml of (0.5N) HClis added to this mixture and stirred using a glass rod.
6. About 2ml of plasticizer (glycerol) is added and agitated. A requirement of a desired pH 0.5N NaOHis added to it.
7. The combination is spread in a petri dish and this is put in the oven at 130ºC and dried for about 30 minutes.
8. The tile is permitted to cool and the film is scraped off the surface. [56].

Reaction mechanism- While making a biofilm, it is highlighted that presence of HCl and NaOH in proper concentration is considered to be a controlling factor for its strength. Using sodium hydroxide in the experiment is merely to neutralize the pH of the medium. Caustic hydrolysis fluctuates the physicochemical properties of starch without changing its particle structure. Additives like plasticizers or dispersants are used to increase the plasticity or fluidity rate of a material. The dominant applications are for plastics, especially polyvinyl chloride (PVC) glycerol, sorbitol. The properties of ingredients are also enhanced when merged with plasticizers including concrete, clays, and similar products. Plasticizers make it probable to attain improved compound processing characteristic features, while also provided flexibility in the end-use creation. Glycerol (also called glycerin) is a humble polyol (sugar alcohol) compound. It is a neutral, unscented, viscous liquid that is sweet-tasting and non-toxic. The sodium metabisulphite (Na2S2O5) is used here as an antioxidant. It inhibits microbial growth in the developed peels. It is used as an antiseptic, antioxidant, and antibacterial agent. it is very soluble in ethanol and water. [56]

Isolation of Cellulose Nanofibers

1. Cellulose nanofibers were isolated from the banana peel bran using a grouping of chemical and mechanical treatments.
2. The banana peel will treat with 5% w/v KOH solution under mechanical stirring at room temperature for 14 hr. Insoluble remainder de-lignified two times with 1% w/v NaClO2 at pH 5.0 at 70 C for 1 h, to ensure effective bleaching of the pulp.
3. Further subjected to second KOH treatment at RT for 14 h. The residue obtained at the end of the second alkaline action was then wide-open to acid hydrolysis using a 1% v/v H2SO4 solution for 1 h at 80ºC to hydrolyze amorphous cellulose and remove mineral traces.
4. The residues attained at the end of each step of the acid-alkali treatment were centrifuged at 10 000 rpm for 20 min at 5ºC. The final CNF deposits achieved was washed well with water and stored at 4ºC.
5. To recover the dispersion of nanofibers, in a two-stage high-pressure homogenizer, the final

observation was submitted to mechanical treatment. [37].

Qualitative Analysis

The following test can carry out to check the chief characteristics of a packaging film-

Tensile Strength- Bioplastic film cut into (2 × 6) cm size or any small section, the film was then hooked onto the retort stand placed 3.5 cm apart. The spring balance hooked onto the middle of the film and weight loaded taking 3 replicate observations obtained until the sample broke apart. The tensile strength calculated by the below formula Equation 1. [38]-

Tensile Strength = Weight Load (N)/ Area of cross-section of biofilm (m2) **…………..**Equation 1

Water Absorption Test-A small section of the sample cut into 1 cm × 2 cm size. The initial weight of the sample recorded accordingly. The sample was then positioned into a beaker containing 60 mL of water at room temperature for 24 hours. The sample taken out from immersion and wiped off. The final weight was recorded. The amount of water uptake calculated by the following formula Equation 2[38]:

WA (%) = Final weight (g)-initial weight (g)/ initial weight (g) × 100 **……………….**Equation 2

Thickness, Density, and Moisture Content**-** The thickness of the film was measured with the relief of a manual micrometer accuracy rate of 0.0001 mm. The mean thickness of every film was firm from a middling of 10 random measurements.

Sample film cut into 20X20 mm squares for determination of the density, and the thickness of films was measured (three random measurements). The film samples were dried at 105º C for 24 hr and balanced, the density was intended as the ratio between the weight and volume (thickness x area) of the film. The density experiments were accomplished by three consecutive readings, and the data are reported as mean values. The moisture content of the films was analyzed gravimetrically, in triplicate, according to the standard method D644-99 [29], by drying the samples at 105º C for 24 hrs. [35, 37].

Solubility in Water**-** Film sample dried for 2 hours in a hot air oven at 70 C and initial weight was recorded. Samples were absorbed in a beaker comprising 50 ml of distilled water and placed in an incubator for 24 hrs. at 30 C. Thereafter, film samples dehydrated in a hot air oven for 24 hours at 90 C. The dried film sample was weighed for determining the weight of the water-soluble solid. Lastly, the water dissolved portion of the dried film sample was calculated using the following formula:

Analyses were carried out by an average of 4 samples, and the solubility in water (%) of the films was calculated as per Equation 3 **[37,60].**

$$S = \frac{W_i - W_f}{W_i} \times 100$$

Equation 3

Where,

Wiis the initial dry weight of the sample (g), and Wf, is the final dry weight of the sample (g).

Scanning Electron Microscopy (SEM) Analysis- This type of electron microscopy emerges images of a particular sample by scanning the testing sample with a focused beam of electrons. Using SEM, surface morphology can be studied in the study. For overnight, the sample oven-dried at 50ºC and coated with a gold film to acquire a clear microscopic image. [35]

CONCLUSION

Following conclusions can be made after idealizing the making of a biodegradable film based on the above method-

- Biodegradable packaging is made from eco-friendly materials. Hence, it is easier to recycle. They require less energy to produce. They are non-toxic with reduced carbon emission and help to reduce climate change. Though biodegradable packaging has various rewarding points over plastics, they too have their limitations. The requirement of plant matter for their production uses long term usage of biodegradable packaging from the plant source. It may also necessitate a special facility for composting. The landfill is another issue emerging due to biodegradation.
- Biodegradable packaging offers the best packaging solution for perishables against microbes and can be the best alternative to plastics when used in conjunction with metal containers. They also offer the best packaging solution for perishables against microbes. The dependence on fossil fuel is condensed due to the probable shift from plastics.
- Pea processing industry wastes can be used for preparing value-added products, which otherwise are discarded or used as animal feed, peels are rich in proximate composition. Bio-films prepared from only pea peel have tensile strength (5.96MPa), thickness (70.00µm), water solubility (2.46%), and transparency and can be utilized as an auxiliary of synthetic plastic and such well-organized management of pea processing waste will lead to secured livelihood, pollution-free surroundings and sustainable improvement.[35]
- Using pea peel waste to express the bio-plastic can provide a sustainable substitute to non-biodegradable plastic and are non-hazardous materials and environmental friendly composites. Bioplastics are established from natural biopolymers, which consist of cellulose, hemicelluloses, and lignin. [57]
- Compared with the other bio-based films, the nanocomposites reinforced with cellulose nanofibers showed better packaging film properties.
- Objective to increase mechanical properties of packaging films can be achieved after adding cellulose nanofibres as cellulose gives excellent mechanical properties with low weight and biodegradable nature that possess high mechanical strength and stiffness, [55] along with the best barrier resilient properties.
- Extraction of these cellulose fibers from a waste brings an option of wastage utilization so as follows this study consist of banana peel for isolation of cellulose fibers as it contains a good amount of cellulose in its peel.
- Properly manufactured composites, according to their end-use, ensure a cleaner environment and harmless situations for human beings.
- Scientific design of cellulose nanofibers and creative methodologies utilizing cellulose Nanofibers can be

obliging for the development of ecological and biodegradable sustainable packaging, with proper measured qualitative and quantitative aspects that can guarantee a sustainable packaging approach for the coming era will surely ensure the efficient production process and its recycling.

- Apart from the above-mentioned test's we can also check the sealing properties of the film- to produce a seal in most form/fill/seal machines. The sealing pressure, sealing temperature, and dwell time are the parameters that should be an inappropriate combination when making a decent seal in the heat-sealing procedure. [58].
- If the results of the test were proper and in the limit of accuracy then we can conclude the experiment as acceptable for future use.

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